Review, Prioritization and Possible Refinements

To the Aerosol STM

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Review of the STM process

- Actually two aerosol STMs
  (a) air quality
  (b) aerosols/clouds/climate

- Science drives the requirements,
  NOT instrument capabilities

- Science requirements need support from peer reviewed literature

Air Quality STM

Category	Focused Questions	Approach	Measurement Requirements	Instrument Requirements	Platform Requirements
Air Quality	What are key region-specific local and distant sources of airborne dust, soot, sulfates, and organics? What are the processes that govern long range aerosol transport and local deposition? What are the trends in anthropogenic and natural contributions to aerosol pollution near the surface?	Retrieval of aerosol optical thickness and column particle microphysical properties by inverting radiance and polarization measurements In order to: (1) Characterize source locations, injection processes, and seasonal/annual fluctuations in emissions. (2) Improve the modeling of processes affecting aerosol transport and deposition. (3) Determine aerosol deposition rates to the surface by type and source.	Global distribution of column optical thickness, effective radius and variance, refractive index, type, number density, and single-scattering albedo of bimodal aerosol population using polarization and radiance measurements.	**Polarimeter** - Swath ~2000 km - At least 3 km horizontal resolution at nadir - Narrow-band photopolarimetric measurements including: o Several intensity +polarization channels in the 400-2200 nm spectral range o Channels to detect and correct for thin cirrus. o Channels to estimate total column water vapor. o Polarization SWIR channels for retrievals over land o 3% radiometric accuracy.. o 0.1% polarization accuracy along the ground track 0.5% polarization accuracy for global coverage	Sun synchronous with crossing time between 10 am and 2 pm
			Spatially sampled distribution of vertically resolved (to within 20 m) optical depth, effective radius, effective variance, refractive index, type, number density, and single-scattering albedo for two modes of the aerosol population over as much of the swath as possible	**Lidar** - Vertical resolution of at least 100 m. - Dual wavelength - 532 & 1064 nm - Dual polarization to separate particle types - HSRL or other technique to obtain direct determination of extinction Better SNR than Calipso **Cross Track Lidar** – measurements extended to 175 km on either side of nadir	
				Polarimeter as above and… Rayleigh scattering + polarization estimates for aerosol altitude. Requires UV channel on polarimeter	

Aerosol/Clouds STM

Category	Focused Questions	Approach	Measurement Requirements			Instrument Requirements	Platform
Aerosols Clouds and Climate	**Aerosols, Clouds and Radiation** How do aerosols affect the Earth's radiation budget (ERB)? How do aerosol affect the radiative properties of clouds (also see section below), and how do these effects vary with aerosol properties? How do the above effects partition between natural and anthropogenic aerosols?	Partitioning of direct radiative forcing by aerosol amount, type, and source. Quantification of aerosol and cloud effects on surface heating rate and the vertical heating rate profile. Quantification of cloud suppression by absorbing aerosols. Quantification of the direct effect of anthropogenic aerosols and cloud suppression by absorbing aerosols.	The desired cloud and aerosol properties can not be obtained from a single instrument, but will require carefully collocated measurements from a variety of instruments. "two swath" approach where vertically resolved measurements are provided on a relatively narrow-swath and imaging polarimeter data and scanning passive microwave data are used to provide additional context over a much larger domain. Retrievals which combine observations from all instruments will be used in narrow-swath region. Wide-swath/imager observations are then combined with retrievals from the narrow-region to improve retrievals over imager-only approaches for the full domain. For mid-trop clouds aerosol sources are less likely to be local and swath coverage becomes more important. Vertically integrated column ice water path from microwave radiometer (which does include some information content on the vertical distribution of ice, though much less than that provided by cloud radar and lidar) is an important addition.	Aerosols	**Horizontal / Imagery-based aerosol properties and heights** - Horizontal resolution 100 m (50 m or better desired). - Total column optical depth to 0.05 or 10%, whichever is larger. - Aerosol properties retrieval requirements, as per aerosol section. - Measurement of vertically resolved (to within 0.5 km) of aerosol height over a broad swath	**Polarimeter** As above plus sufficient angles and wavelengths to provide : - stereo cloud-top-heights - stereo cloud-top-winds - cloud particle size - cloud-particle phase and limited ice crystal habit characterization. - long slant paths through the atmosphere (increasing sensitivity for thin clouds) Desired: Polarization and angular capability for "rainbow" retrieval of particle size for water clouds	Sun synchronous with crossing time between 10 am and 2 pm
					Vertical / Lidar resolved aerosol properties - Vertical resolution of 100 m or better. - Horizontal resolution of 500 m or better. - Aerosol properties retrieval requirements, as per aerosol section.	**Lidar** As above	Orbit altitude between 450 and 650 km
					Broadband longwave and shortwave radiance measurements with accuracy at least as good as the current CERES instrument.	**Broadband ERB** Measurement broadband Earth-reflected solar shortwave (0.3 - 5.0 micrometer) and Earth-emitted long wave (5.0 - greater than 100 micrometer) radiances as well as emitted longwave radiances in the 8 - 12 micrometer water vapor window over geographical footprints 10 kilometers at the nadir.	Need to co-fly with ERB instruments or include ERB sensor on payload
	Cloud-Aerosol Processes How do different types of aerosols affect cloud cover, cloud phase, cloud water content and cloud particle size for water clouds, mixed phase clouds and ice clouds? How do these factors affect cloud albedo? Are clouds fundamentally brighter in conditions of heavy aerosol? Do aerosols exert a significant effect on the environmental controls on cloud life cycle processes? How do aerosols affect warm and cold precipitation processes? How do different cloud types influence aerosol number and mass concentration, vertical profile and size distribution? Do changing aerosols significantly control the initiation of precipitation? What factors establish the precipitation efficiency of weather systems, and is this efficiency influenced by aerosols?	Quantification of changes in cloud properties and brightness (IDE) due to natural and anthropogenic aerosols and isolating these effects from meteorology, large-scale forcing, and other factors. Quantification of changes in aerosol properties in the presence of clouds Determination of precipitation rates within clouds. Differentiation between precipitating cloud condensate and non-precipitating condensate and between types of precipitating condensate Determine cloud macrophysical properties (horizontal coverage, vertical extent and cloud-top-height) and microphysical properties (total column optical depth, vertically resolved cloud phase, water content and particle size) in both clean and aerosol loaded environments. Determine aerosol optical properties (total column optical depth, column average single-scattering albedo, vertically resolved extinction, as well as some measure of column-effective particle size and sphericity in clear-skies including the near-vicinity of clouds, especially broken cumulus. Aggregate cloud properties as a function of aerosol optical properties, as well as ancillary data on the atmospheric dynamical state, likely aerosol type, distance of aerosol from source of origin, etc, to determine if there are significant changes in clouds properties with these other variables. Cirrus clouds with optical depths greater than 0.05 must be identified and incorporated into combined aerosol-cloud retrievals.		B'ndary Layer Clouds	**Horizontal / Imager-based cloud properties** - Coverage (cloud detection) with horizontal resolution of at least 100 m (50 m or better desired). Failed detection rate less than 1% and a false detection rate less than 4%. - Total column optical depth to better than 50% clouds with a total optical depth greater than 1. - Column effective particle radius to 20% or better for single phase clouds. - Cloud-top-height to 50m or better with uncertainty of less than 50 m. - Effective visible-wavelength cloud-phase with low probability of false determination (less than 20%). Measurement of aerosol properties as above **Vertical / Radar resolved cloud properties** - Vertical resolution of 120 m minimum (30 to 60 m desired). - Horizontal footprint / field of view 500 m or better - Ice/Liquid water content to 50% or better for clouds single-phase clouds. - Cloud particle size to 20% or better for single-phase clouds.	**Thermal IR Cloud Sensor** - Capability to estimate cloud height to ~1 km - Compatibility with VIIRS and current EOS sensors IR bands - wavelengths: 3.7, 8.5, 11, 12, several CO_2 bands near 13 um. - Calibration to at least 0.5K.	none
						Polarimeter As above	Sun synchronous with crossing time between 10 am and 2 pm
						Backscatter Lidar **As above**	Orbit altitude near 450 km recommended.
						Cloud Radar - vertical resolution: 120 m (or better) - horizontal footprint: 1/2 km - Sensitivity of better than -30 dBZe (-40 dBZe desired) - Dual frequency (94&34GHZ) Scanning or Multibeam capability recommended	
				Mid-trop. clouds and convective clouds	**Horizontal / Imager-based cloud properties** - Coverage (cloud detection) with horizontal resolution of at least 500 m. - Failed detection rate less than 1% and a false detection rate less than 4%. - Cloud Properties retrievals, as per boundary layer clouds **Horizontal / high frequency scanning radiometer for ice cloud properties** - Horizontal resolution: a few km - Ice water path (IWP) to 50%. **Vertical / Radar resolved cloud properties** - Vertical resolution of 240 m (minimum). - Horizontal resolution: 1 to 2 km. - Cloud Properties retrievals, as per boundary layer clouds. **Horizontal / Imagery-based aerosol properties** - Horizontal resolution ~ few km. - Aerosol properties retrieval requirements, as per aerosol section. **Vertical / Lidar resolved aerosol properties** - Vertical resolution of 240 m or better. - Horizontal resolution of 500 m or better. - Aerosol properties retrieval requirements, as per aerosol section. **Swath width** - Passive Instruments: Minimum 400 km Active instruments: Scanning or multiple beams are not indispensable but strongly desire	**Polarimeter** As above but 250-500m horizontal resolution	Sun synchronous with crossing time between 10 am and 2 pm Orbit altitude between 450 and 650 km
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						High Frequency µ-wave Radiometer for IWC and cloud ice properties in combination with radar. Conically scanning ~53deg incidence angle: 800-183 GHz. Footprint ~10 km	
						Low Frequency µ-wave Wide swath microwave radiometer for bulk water contents and precipitation also to be matched to radar Conically scanning ~53deg incidence angle: 10.65-183 GHz Footprint: ~10 km	

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Focused questions

Cloud-Aerosol Processes

How do different types of aerosols affect cloud cover, cloud phase, cloud water content and cloud particle size for water clouds, mixed phase clouds and ice clouds? How do these factors affect cloud albedo?

Are clouds fundamentally brighter in conditions of heavy aerosol?

Do aerosols exert a significant effect on the environmental controls on cloud life cycle processes?

How do aerosols affect warm and cold precipitation processes?

How do different cloud types influence aerosol number and mass concentration, vertical profile and size distribution?

Do changing aerosols significantly control the initiation of precipitation?

What factors establish the precipitation efficiency of weather systems, and is this efficiency influenced by aerosols?

Approach

Quantification of changes in cloud properties and brightness (IDE) due to natural and anthropogenic aerosols and isolating these effects from meteorology, large-scale forcing, and other factors.

Quantification of changes in aerosol properties in the presence of clouds

Determination of precipitation rates within clouds.

Differentiation between precipitating cloud condensate and non-precipitating condensate and between types of precipitating condensate

Determine cloud macrophysical properties (horizontal coverage, vertical extent and cloud-top-height) and microphysical properties (total column optical depth, vertically resolved cloud phase, water content and particle size) in both clean and aerosol loaded environments.

Determine aerosol optical properties (total column optical depth, column average single-scattering albedo, vertically resolved extinction, as well as some measure of column-effective particle size and sphericity in clear-skies including the near-vicinity of clouds, especially broken cumulus.

Aggregate cloud properties as a function of aerosol optical properties, as well as ancillary data on the atmospheric dynamical state, likely aerosol type, distance of aerosol from source of origin, etc. to determine if there are significant changes in clouds properties with these other variables.

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STM

Measurement Requirements

The desired cloud and aerosol properties can not be obtained from a single instrument, but will require carefully collocated measurements from a variety of instruments.

"two swath" approach where vertically resolved measurements are provided on a relatively narrow-swath and imaging polarimeter data and scanning passive microwave data are used to provide additional context over a much larger domain.

Retrievals which combine observations from all instruments will be used in narrow-swath region.

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Vertically integrated column ice water path from microwave radiometer (which does include some information content on the vertical distribution of ice, though much less than that provided by cloud radar and lidar) is an important addition.

White paper

Appendix A
Aerosol and cloud satellite retrieval accuracy requirements

Common requirements

- All aerosol retrievals (column and vertically resolved) must be performed for at least two co-existing particle modes;
- aerosol optical thickness (AOT), column (±0.02 or ±0.05*tau, at least in three spectral channels covering the broad range 400 to 2200 nm, over both land and oceans);
- aerosol morphology, column (spherical, irregular dust, soot clusters);
- the ability to separate clouds and aerosols, including cirrus;
- the ability to make all retrievals over all surface types: ocean, vegetation, deserts, snow, and above clouds;
- spatial resolution ~5 km for column quantities;
- global coverage ~2 days for column quantities;

vertical spatial resolution for vertically resolved parameters ~300 m.

A1.1. Partitioning of direct radiative forcing by aerosol amount, type, and source

A1.2. Quantification of aerosol and cloud effects on surface heating rate and the vertical heating rate profile

A1.3. Quantification of cloud suppression by absorbing aerosols

A1.4. Quantification of the direct effect of anthropogenic aerosols

- **A1.4.a. To quantify the aerosol direct effect**
- **A1.4.b. To constrain chemical composition and origin**

A1.5. Quantification of changes in cloud properties and brightness (IDE) due to natural and anthropogenic aerosols and isolating these effects from meteorology, large-scale forcing, and other factors

A1.6. Quantification of changes in aerosol properties in the presence of clouds

A1.6. Quantification of changes in aerosol properties in the presence of clouds

passive parameters produced for horizontal spatial resolution ~0.5 km;
~5 km if simultaneous aerosol and cloud retrievals
within the same pixel are possible

This represents just one area where the group could
NOT come to consensus

		Instrument Requirements	Platform
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Mid-trop	**Horizontal / Imager-based cloud**	**Polarimeter**	Sun

	for single-phase clouds.		
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The point is…

Different science requirements for different objectives all filed under ‘aerosols’

Different measurement requirements for different objectives all using the same instruments

The Appendix of the white paper is a better source for linking objectives to requirements than the STM

There are several places where the group could NOT come to consensus

Summary:

High accuracy has to balance coverage
(two path approach)

To do the complete job:
polarimeter, lidar, thermal, broadband, radar are all needed

Sub-orbital measurements are VITAL components of the
ACE mission and not just CAL/VAL.

Designs of specific instruments left open
HSRL vs. multi-beam backscattering lidar
number of angles in polarimeter
dual frequency vs. scanning radar

Points of disagreement:

Orbit altitude

Horizontal spatial resolution

Spatial resolution constraints on multiangle measurements
Of changing cloud fields

Cloud/aerosol separation in polarimetry